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Report of a Pest Risk Analysis

This summary presents the main features of a pest risk analysis which has been conducted on the pest, according to EPPO Decision support scheme for quarantine pests.

Pest:	*Eichhornia crassipes* (Martius) Solms
PRA area:	The EPPO Region.
Assessor:	The Expert Working Group on *Eichhornia crassipes* composed of: Julie Coetzee (South-Africa), Martin Hill (South-Africa), Angel Hurtado (Spain), Célia Laranjeira (Portugal), Michael Nang'alelwa (Zambia), Trinidad Ruiz Téllez (Spain), Gritta Schrader (Germany), Uwe Starfinger (Germany) With the help of Mic Julien (Australia).
Date:	2008-06-12

STAGE 1: INITIATION

Reason for doing PRA:	*E. crassipes* is considered one of the worst aquatic invasive plant worldwide (Harley *et al*., 1996). It is a threat in Spain and Portugal, but its distribution is currently limited in the EPPO region.
Taxonomic position of pest:	Spermatophyta Angiospermae (Magnoliophyta) Monocotyledones (Liliopsida) Liliales Pontederiaceae There are no described subspecies or varieties.

STAGE 2: PEST RISK ASSESSMENT

Probability of introduction

Entry

<u>Geographical distribution:</u>

EPPO region: Israel, Italy, Jordan, Portugal, Spain
Asia: Bangladesh, Cambodia, China, Brunei Darussalam, India, Indonesia, Lebanon, Japan, Laos, Malaysia, Maldives, Myanmar, Philippines, Singapore, South Korea, Sri Lanka, Syria, Taiwan, Thailand, Viet Nam,
North America: Mexico, USA (Alabama, California, Florida, Georgia, Hawaii, Louisiana, Mississippi, Texas). See the USGS/Florida Caribbean Science Center map from the "Protect your waters" website.
Central America: Costa Rica, Guatemala, Honduras,

	Nicaragua, Panama, **South America:** Argentina, Bolivia, Brazil, Chile, Columbia, Ecuador, French Guiana, Guyana; Uruguay, Paraguay, Peru, Suriname; Venezuela. **Caribbean**: Bahamas, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico. **Oceania:** American Samoa, Australia, Cook Islands, Fiji, French Polynesia, Guam, Marshall Islands, Federated States of Micronesia, Nauru, New Caledonia, New Zealand, Northern Mariana Islands, Palau, Papua New Guinea, Samoa, Solomon Islands, United States minor outlying islands, Vanuatu. **Africa:** Angola, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of Congo, Egypt, Equatorial Guinea, Ethiopia, Gabon, Ghana, Guinea, Guinea Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Niger, Nigeria, Reunion, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia and Zimbabwe.
Major host plants or habitats:	Freshwater bodies and ecosystems.
Which pathway(s) is the pest likely to be introduced on:	Intentional import of the plant for ornamental purposes is the most important pathway. Intentional import for agricultural, energy, waste water treatment and research purposes could also be a potential pathway but this is currently considered to be minor.

Establishment

Plants or habitats at risk in the PRA area:	Freshwater bodies and ecosystems.
Climatic similarity of present distribution with PRA area (or parts thereof):	Very similar in southern Europe to totally dissimilar in northern Europe. Optimal growth occurs at temperatures of 28-30^{o}C (air temperatures) while growth ceases when water temperatures drop below 10ºC (Gopal, 1987). During these times of stress, stored carbohydrates from the rhizome are used as energy reserves (Owens and Madsen 1995), but prolonged cold temperatures, below 5^{o}C, result in death of the plants, limiting *E. crassipes* distribution in high latitudes (Gopal 1987, Owens and Madsen 1995). See Appendix 1. Transient populations of the weed are likely to occur in the more temperate regions of Europe, where population expansion is likely through the summer months and retraction during winter, as it is the case in canals in the Netherlands for *E. crassipes* (Bruinsma, 2000). It is not known whether the plant could set seeds during summer in these areas, and whether the crown could survive, protected by dead parts of the plant.

Aspects of the pest's biology that would favour establishment:

Another species is not needed to complete the life cycle of the plant. The plant is able to reproduce vegetatively.

E. crassipes is a highly competitive floating macrophyte that is capable of outcompeting other species of invasive floating macrophytes throughout the world such as *Salvinia molesta, Pistia stratiotes, Myriophyllum aquaticum, Azolla filiculoides* (Coetzee *et al.* 2005).
In Spain, all associated species both on banks (*Phragmites communis*, *Typha latifolia*, *T. angustifolia*, etc.) and in water (*Lemna minor, Azolla filliculoides*) were affected by the fast growth of *E. crassipes*. Initially, *E. crassipes* would coexist with other aquatic plants, but soon outcompetes these species (Ruiz Téllez *et al*., 2008a).

So far, no natural enemies have been reported on *E. crassipes* in the EPPO region.

Each flower of *E. crassipes* produces about 250 long-lived seeds (up to 20 years) (Barrett, 1980) that are resistant to the drying up of the water body. Germination occurs once the water body is re-inundated and the plants are then capable of rapid growth through the asexual production of daughter plants (Watson and Cook, 1987).
In Spain (River Guadiana), *E. crassipes* reproduces both vegetatively and sexually and has floral cycles of about 1-2 days, and 1-2 months to produce mature dehiscent fruits and seeds (GIC, 2006).

Its doubling time can be as little as one week (Edwards and Musil, 1975), and depends on water nutrient content and temperature. In the Guadiana river in Spain, doubling time varied between 10 and 60 days (Ruiz Téllez *et al*., 2008a).

The lack of genetic diversity is no constraint to its invasiveness (Li *et al.,* 2006).

Characteristics (other than climatic) of the PRA area that would favour establishment:

Freshwater bodies and ecosystems abound in the EPPO region.

E. crassipes can tolerate pH levels from 4.0 to 10.0, ideally 6 to 8 (Ruiz Téllez *et al*., 2008a). It grows best in water high in nutrients (for precise figures, see Ruiz Téllez *et al*., 2008a, Agami *et al*., 1989 and 1990). Salinities of more than 25‰ kill the plants. With regards to luminance, the species is heliophilous and needs between 24.000 to 240.000 lux (François, 1969).
E. crassipes can tolerate water level fluctuations, whereby plants stranded on the banks of the water body are capable of surviving for several months provided the banks are moist. Further, the plant is able to survive in ephemeral water bodies as the seeds are resistant to desiccation and germinate once the water body is re-inundated (Gopal,

1987).
These abiotic conditions are very similar to the ones occurring in the EPPO region, e.g. in Spain and Portugal (Moreira *et al*., 2005; Ruiz Téllez *et al.* 2008a).

Two factors contribute to the establishment of *E. crassipes*:

- increased nutrient status through agricultural, urban and industrial run-offs
- and impoundment of waters by creating dams, altering hydrological regimes (Ruiz Téllez *et al*., 2008a, Hill and Olckers, 2001).

Which part of the PRA area is the endangered area:

The most endangered part of the PRA area is freshwater bodies and ecosystems in the southern parts of the EPPO region.
The countries the most at risk are: Albania, Algeria, Bosnia and Herzegovina, Croatia, France (including Corsica), Greece, Israel, Italy (including Sardinia, Sicilia), Jordan, Montenegro, Morocco, Portugal (Azores, Madeira), Slovenia, Spain (Baleares, Canarias), Turkey, Tunisia.

Freshwater bodies and ecosystems of more temperate areas are also susceptible to transient infestations. Countries of western and central Europe would be the more at risk (e.g. the UK, the Netherlands).

POTENTIAL ECONOMIC CONSEQUENCES

How much economic impact does the pest have in its present distribution:

Impacts to crop yield and control costs

The most important impacts of the plant on crop yield are caused by water loss. *E. crassipes* increases water loss due to evapo-transpiration. Estimates of increased water loss vary from 2.67 times (Lallana *et al,* 1987) to 3.2 times (Penfound and Earl, 1948) more from a mat of *E. crassipes* in comparison to open water. Lallana *et al.* (1987) calculated that *E. crassipes* caused an increase in water loss of about 70 000 l/ha/d from a dam in Argentina. Furthermore, there is a direct cost to irrigation infrastructure including irrigation canals and pumps (Gopal, 1987).

E. crassipes impacts agriculture production worldwide. As an example, in Portugal, negative impacts have caused big economic losses to rice fields and local farmers of the Sado River Basin (Guerreiro, 1976; Moreira *et al*., 1999). *E. crassipes* impacts rice production in 3 ways: direct suppression of the crop and inhibition of its germination, water loss and increase in costs in harvesting since the plants get caught up in the mechanical harvester. Globally, Gopal (1987) reported impacts on rice production with inhibition of the seed germination in India, Sri Lanka, Bangladesh (cost of 15 millions dollars according to Kar, 1939, in Gopal 1987), Burma, Malaysia, Indonesia, Thailand, Philippines, Japan, and Portugal. According to Parson and Cuthbertson (2001), losses are staggering, for example, in the Indian State of West Bengal, it causes an annual loss of paddy rice valued at 110 million rupees. Impacts are also reported on rape seed in Japan (Ahmed *et al*., 1982 in Gopal 1987).

E. crassipes has been reported to be an alternative host for the Asian corn borer, *Ostrinia furnacalis* Guenee and the rice root nematode, *Hirschmanniella oryzae* (van Breda de Haan) Luc and Goody (Grove *et al.*, 1995).

Figures on general costs of control are available throughout the world, though, a separation between costs for agricultural purposes and other purposes cannot be made.

Between 1980 and 1991, Florida spent over $43 million to suppress *E. crassipes* and *Pistia stratiotes* (Schmitz *et al*. 1993). Currently, annual costs for *E. crassipes* management range from $500,000 in California to $3 million in Florida (Mullin *et al*. 2000). The largest infestations of *E. crassipes* in the USA occur in Louisiana where the Department of Fisheries treats about 25,000 acres of *E. crassipes* with herbicides per year, mostly at boat ramps, at an annual cost of $2 million.

Within its present range within the PRA area, the management cost to remove nearly 200,000 tonnes of the plant was 14,680,000 euros for 2005 to 2008 in the Guadiana river (for around 75 km of river) (Cifuentes *et al*. 2007, Ministry of the Environment of Spain). It represents 65,723 working days and necessitates the use of crane trucks equipped with a grapple, backhoes with bucket, and 35 meters boom cranes (Ruiz Téllez *et al.*, 2008b).

In Portugal, the management in the Municipality of Agueda cost 278,000 euros from December 2006 to May 2008, including the purchase of the mechanical harvester and its monthly running costs (Laranjeira, 2008). A water harvester and a truck were used.

Moreira *et al*. (2005) and Santos (2003) report that 470,000 euros were spent during 1999 to 2004 near Leziria Grande de Vila Franca de Xira (Portugal) for an integrated management programme.

Environmental impacts

Dense mats of *E. crassipes* reduce light to submerged plants, thus depleting oxygen in aquatic communities (Ultsch, 1973). The resultant lack of phytoplankton (McVea and Boyd, 1975) alters the composition of invertebrate communities (Hansen *et al*., 1971; O’Hara, 1967), ultimately affecting fisheries. Drifting mats scour vegetation, destroying native plants and wildlife habitat. *E. crassipes* also competes with other plants, often displacing wildlife forage and habitats (Center *et al.*, 1999). Higher sediment loading occurs under *E. crassipes* mats due to increased detritus production and siltation. Annual fish and wildlife losses associated with *E. crassipes* infestations in six South-Eastern states of the USA exceeded $4 million per year in 1947 (Tabita and Woods, 1962).

Midgley *et al.* (2006) investigated the impact of *E. crassipes* on abundance and diversity of benthic invertebrates and chlorophyll *a* at a site in the Eastern Cape Province of South Africa. They showed that species richness, diversity and abundance and the concentration of chlorophyll *a* were significantly negatively affected by a cover of *E. crassipes*. The plant has also been linked to a reduction in the diversity of water fowl on the Nseleni River, KwaZulu-Natal, South Africa (Jones, 2001).

Social impacts

Recreation and tourism

In some areas of the world, *E. crassipes* infestations have had a negative effect on waterfront real estate values and consumer driven recreational use of water bodies (GIC, 2006).

Water quality

E. crassipes has a negative effect on the quality and quantity of potable water. *E. crassipes* blocks light penetration to the water column and leads to a reduction in oxygenation of the water and a build-up of sulphur dioxide, causing the water to smell and taste bad. The water treatment plant for Lusaka in Zambia was forced to retain the water in the plant for further treatment due to a reduction in the water quality drawn from the Kafue River that was infested with *E. crassipes* (Hill *et al*., 1999).

Hydroelectric power production

E. crassipes threatens the production of electricity through hydropower generation throughout Africa. A few examples have been noted in the literature. The hydropower station at the Kafue Gorge Dam in Zambia is responsible for supplying 900MW of power to the country. At the height of the *E. crassipes* problem on the dam, at least one of the 5 turbines was forced to be shut down for a day per week. This was due to the increased concentration of nitrous oxides in the water that caused a certain amount of corrosion on the turbines. The hydropower dams on the Shire River in Malawi and the Owen Falls Dam at Jinga in Uganda on the Nile River are also frequently forced to stop production due to *E. crassipes* clogging the intakes for the water cooling system. No estimates of costs of this are available, but it must amount to several million USD per year (Wise *et al*., 2007).

The impact of the plant in 2007/2008 on the Victoria Falls Power Station amounted to USD 946,822 (Nang'alelwa, 2008).

Case study

Lake Victoria is the world's largest fresh water tropical lake and has been heavily impacted by *E. crassipes*. The weed was first recorded on the lake in around 1990 but by 1998 covered some 20,000 ha of the lake (Albright *et al*. 2004). The lake basin supports some 25 million people and has an estimated value of some USD 4 billion annually, with fishing benefiting the livelihood of at least 500,000 people and having a potential sustainable fishery export value of USD 288 million (Albright *et al*., 2004). *E. crassipes* severely threatened the economic activities on the lake and the development of the region. Economic impacts in Uganda in 1995 were estimated by Mailu (2001) at:

- Maintaining a clear passage for ships to dock at Port Bell in Uganda were USD 3-5 million
- Clearing the intake screens at Owen Falls hydroelectric plant were USD 1 million
- Losses in fisheries were about USD 0.2 million
- Losses in beaches, water supply for domestic, stock and agricultural purposes were USD 0.35 million

Sociological impacts such as lack of clean water, increase in vector-borne diseases, migration of communities, social conflict and biodiversity losses were not calculated.

Human health

E. crassipes infestations intensify mosquito problems by hindering insecticide application, interfering with predators such as fish, increasing habitat for species that attach to plants, and impeding runoff and water circulation (Seabrook, 1962). Despite there being numerous references attributing an increase in malaria to *E. crassipes* infestations, in one of the quantified surveys, Mailu (2001) was unable to show a correlation between the explosion of *E. crassipes* on Lake Victoria and an increase in the disease. *E. crassipes* provides the ideal habitat for the snail vectors (*Biomphalaria* spp. and *Bulinus* spp.) of the bilharzia schistosome and there is some evidence from Ghana that increased infestations of *E. crassipes* are linked to an increase in the prevalence of this disease. It also blocks access to water points and, as such, has been linked to an increase in cholera and typhoid (Navarro and Phiri, 2000). Furthermore, *E. crassipes* harbours venomous snakes, crocodiles and hippos making the collection of water dangerous, sometimes fatal (Gopal, 1987; Navarro and Phiri, 2000).

Describe damage to potential hosts in PRA area:	See previous question.
How much economic impact would the pest have in the PRA area:	Impacts to crop yield and control costs Impacts within the EPPO region would be as described in others parts of the world and in Spain and Portugal and would be exacerbated without any control measures. Environmental impacts *E. crassipes* will have a major negative impact on aquatic biodiversity (see above) where it is able to establish. Spanish researchers (GIC, 2006) have reported losses of plankton diversity in the Guadiana River in 2005. Because the invasive turtle *Trachemys scripta* feeds on *E. crassipes,* it can increase its populations. This invasive turtle is already present in the Guadiana in Spain (Acuña Mesén, 1993), as well as in other parts of Spain, France, Italy, Poland (Global Invasive Species Database). Social impacts Recreation and tourism In Spain and Portugal, impacts have been noted in fisheries, recreation water sport, boat navigation, aesthetic impacts (GIC, 2006; Laranjeira, 2008). This has also affected tourism. These impacts would be considered to be similar in other EPPO countries at risk. Quality of potable water EPPO countries relying on surface water supply could be impacted by *E. crassipes*. Hydroelectrical power stations As described in other parts of the world, hydroelectrical power stations could be impacted in EPPO countries at risk. Human health At present, malaria continues to pose a challenge in 8 out of the 52 Member States of the WTO European region, namely Armenia, Azerbaijan, Georgia, Kyrgyzstan, Tajikistan, Turkey, Turkmenistan and Uzbekistan (World Health Organization Regional Office for Europe, 2006). The WHO regional Committee for Europe has in its orientation programme 2006-2007 targeted Schistosomiasis for intensified control (WHO Regional Committee for Europe, 2004). The control of the vectors of this disease would be more difficult due to the presence of *E. crassipes* in these countries.

CONCLUSIONS OF PEST RISK ASSESSMENT

Summarize the major factors that influence the acceptability of the risk from this pest:	The species is imported for ornamental purposes all year round in the EPPO region, and is distributed throughout the EPPO region. The species transfer very easily to unintended habitats (freshwater bodies and ecosystems) and spreads very fast both naturally and helped by human activities. Based on its reproductive strategy, *E. crassipes* is a very successful invader. Gutiérriez *et al*. (1996) stated that considering reproductive abilities of the plant, its resistance to adverse conditions, it is impossible to eradicate it once established. The whole Mediterranean area is suitable for its establishment, and it cost 14,680,000 euros for 2005 to 2008 in the Guadiana river in Spain (for around 75 km of river) (Cifuentes *et al*. 2007, Ministry of the Environment of Spain) to be controlled.
Estimate the probability of entry:	Very high. *E. crassipes* has already entered and is traded within the EPPO region.
Estimate the probability of establishment:	Very high. - *E. crassipes* is already established in some countries of the EPPO region - Greatest risk of establishment: Mediterranean EPPO region - Medium risk: Western and Central Europe, where transient populations occur, e.g. the Netherlands, the UK, Belgium. - Least likely: establishment in Northern and Eastern EPPO countries.
Estimate the potential economic impact:	Very high. Impacts will occur in freshwater bodies and ecosystems (see previous answer) and are described as follows: - Agricultural impacts: irrigation, abstraction, impacts on some crops (e.g. rice), high costs of control - Environmental impacts: loss of biodiversity, modification of habitats - Social impacts: hydropower generation, recreation, quality of water, human diseases.
Degree of uncertainty	The main uncertainty are the climatic requirements of the species, especially the capacity of the species to be cold tolerant, influencing its ability to establish in more temperate countries, e.g. on the Atlantic coast in France and England. It is not known whether the plant could set seeds during summer in these areas, and whether the crown could survive, protected by dead parts of the plant.
OVERALL CONCLUSIONS	*E. crassipes* is the most damaging aquatic weed in the

	world (Holm *et al*., 1969; Global Invasive Species Database). It has impacted freshwater systems on most continents. At this stage the plant is relatively localized within Europe. Every effort should be made to control the weed. The risk of establishment, spread and impact is extremely high

It could be useful for the recipient of this report to receive an illustration, either of the pest itself or of the damage it causes.

STAGE 3: PEST RISK MANAGEMENT

IDENTIFICATION OF THE PATHWAYS

Pathways studied in the pest risk management	Intentional import of the plant for ornamental purposes
Other pathways identified but not studied	Intentional import for agricultural, energy, waste water treatment and research purposes could also be a potential pathway but this is currently considered to be minor. Unintentional import as a contaminant. The experts considered that contaminants are usually vegetative parts of aquatic plants, which is very unlikely for *E. crassipes* since daughter plants are big, and seeds would have to be introduced through sediments.

IDENTIFICATION OF POSSIBLE MEASURES

Possible measures for pathways	Prohibition of the import of the plant.
Measures related to consignments:	
Measures related to the crop or to places of production:	
Other possible measures	Prohibition of selling, transport, planting and causing to grow in the wild, possession of the plant. Management measures are also recommended: - Integrated management plan for the control of existing infestations - Monitoring/surveillance: Early detection in the countries at risk - Emergency plan: rapid response to new infestations The main control options are: mechanical control, herbicide application and biological control. Possibly the most sustainable option is to integrate these methods with a reduction in nutrient input. Nevertheless, herbicides are usually prohibited in aquatic ecosystems. In Europe, the release of biological control agents may be subjected to specific procedures nationally and has to be in accordance with EU regulations. This implies that mechanical control is currently the only

option. However, it is labour intensive and requires repeated follow ups.

- Obligations to report findings, in the whole EPPO region, especially in the Mediterranean area
- Proposal of alternative non invasive aquatic species for use
- Publicity: public awareness campaigns about the impacts of the plant with the information not to use it as an ornamental, fodder, or decontaminant of waste waters.

See the EPPO Standard PM 3/67 'Guidelines for the management of invasive alien plants or potentially invasive alien plants which are intended for import or have been intentionally imported'.
See the EPPO PM9 on *Eichhornia crassipes* as well as the Code of conduct on horticulture and invasive alien plants developed by the Council of Europe (Heywood and Brunel, to be published).

EVALUATION OF THE MEASURES IDENTIFIED IN RELATION TO THE RISKS PRESENTED BY THE PATHWAYS

Degree of uncertainty Low

CONCLUSION:

Recommendation for possible measures (type presentation):

Intentional import of the plant for ornamental purposes	Prohibition.

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Appendix 1

Climatic prediction for *Eichhornia crassipes*

Document prepared by the EPPO Secretariat and Darren Kriticos (CSIRO-ENSIS)

The CLIMEX model is a computer programme aiming at predicting the potential geographical distribution of an organism considering its climatic requirements. It is based on the hypothesis that climate is an essential factor for the establishment of a species in a country.

CLIMEX provides tools for predicting and mapping the potential distribution of an organism based on:

(a) climatic similarities between areas where the organism occurs and the areas under investigation (Match Index),
(b) a combination of the climate in the area where the organism occurs and the organism's climatic responses, obtained either by practical experimentation and research or through iterative use of CLIMEX (Ecoclimatic Index).

For *Eichhornia crassipes*, a compare location analysis has been undertaken.

1. Geographical distribution of the species

The global distribution of E. crassipes was assembled from a number of sources. *Eichhornia crassipes* is distributed throughout the world, flourishing in tropical and subtropical regions, and it seems to tend to extend to Mediterranean climatic areas (see question 10 and the datasheet for the enumeration of countries where the species is naturalized).
Data have both been provided at the country level (in pink), and at the location level, when data was available.

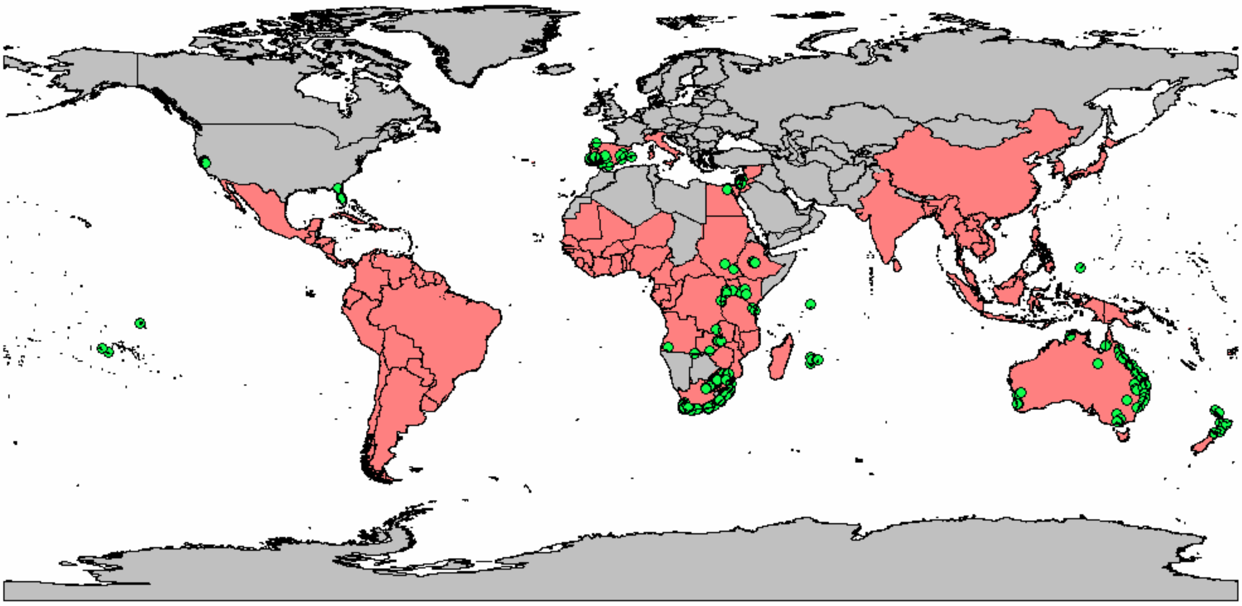


Figure 1: distribution of *Eichhornia crassipes* in the world

1.1.1 Phenology and Environment

Eichhornia crassipes flowers year-round in mild climates, producing abundant amounts of long-lived seeds. However it has been reported that sexual reproduction is limited, and although the plant flowers profusely, few observers have seen seeds or seedlings in the field (Gopal 1987).

1.1.2 Influence of climatic factors on distribution

Rainfall

Being aquatic, the plant is highly dependent upon the presence of standing water. As this is a function of precipitation, evaporation, meso-topography and human practices, we decided to treat the presence of standing water separately from the other climatic factors.

Temperature

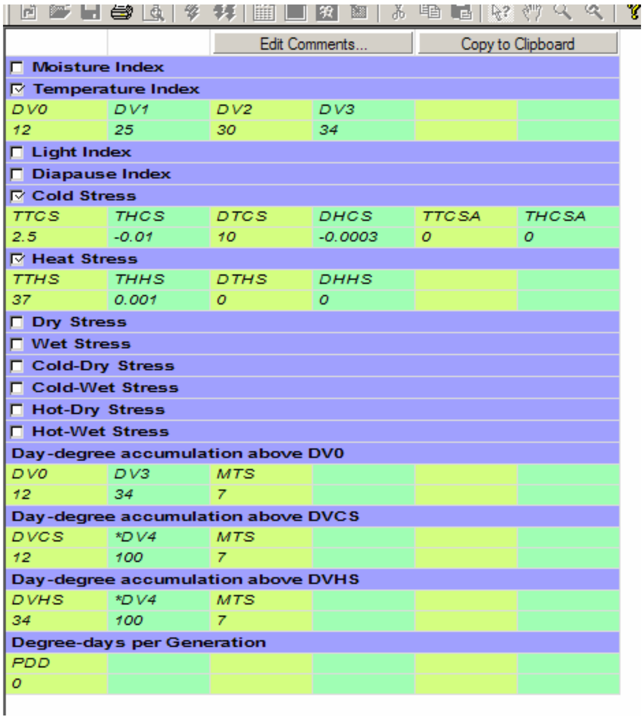
Eichhornia crassipes is reported to be winter hardy, but sensitive to frost. Frosts kill the leaves and upper petioles which protect the rhizome, but prolonged cold temperatures, below 5 ^{o}C, may kill the rhizome resulting in death of the plants (Owens and Madsen 1995).

Kasselmann (1995) reported that its minimum growth temperature is 12 °C, its optimum growth temperature is 25-30 °C, and its maximum growth temperature is 33-35 ° C. Owens and Madsen (1995) report that optimal growth occurs at temperatures of 28 to 30^{o}C, while growth ceases when water temperatures drop below 10ºC and it is retarded above 34ºC. It is assumed that these reported temperatures are air temperatures.

FITTING PARAMETERS

The parameters used in the CLIMEX model for *E. crassipes* are summarized in Table 1. The role and meaning of these parameters are fully described in Sutherst *et al*. (2004), and their values are discussed below. It should be noted that the meteorological data used in this model represent long-term monthly averages, not daily values. This means that it is not possible to compare directly values derived using the model with instantaneous values derived through direct observations. This applies mostly to parameters relating to maximum and minimum temperatures.

The climatic requirements of *E. crassipes* were derived by fitting the predicted distribution to the known distribution outside Europe, and then comparing the predicted and known distributions within Europe.



☐ **Moisture Index**					
☑ **Temperature Index**					
DV0	*DV1*	*DV2*	*DV3*		
12	*25*	*30*	*34*		
☐ **Light Index**					
☐ **Diapause Index**					
☑ **Cold Stress**					
TTCS	*THCS*	*DTCS*	*DHCS*	*TTCSA*	*THCSA*
2.5	*-0.01*	*10*	*-0.0003*	*0*	*0*
☑ **Heat Stress**					
TTHS	*THHS*	*DTHS*	*DHHS*		
37	*0.001*	*0*	*0*		
☐ **Dry Stress**					
☐ **Wet Stress**					
☐ **Cold-Dry Stress**					
☐ **Cold-Wet Stress**					
☐ **Hot-Dry Stress**					
☐ **Hot-Wet Stress**					
Day-degree accumulation above DV0					
DV0	*DV3*	*MTS*			
12	*34*	*7*			
Day-degree accumulation above DVCS					
DVCS	**DV4*	*MTS*			
12	*100*	*7*			
Day-degree accumulation above DVHS					
DVHS	**DV4*	*MTS*			
34	*100*	*7*			
Degree-days per Generation					
PDD					
0					

Fig 2: parameters used for *Eichhornia crassipes*

Stresses indices

In CLIMEX, stress indices indicate negative population growth potential and vary between 0 and ∞, where a value of 100 or greater indicates lethal conditions. When threshold conditions are exceeded, stresses accumulate on a compounding weekly basis. The thresholds and accumulation rates are user-defined parameters. Wet stress is not considered since the species is aquatic.

Dry stress
It is considered that the plant do not suffer from drought since it is aquatic. Moreover, the plant is present in Egypt which is a very dry country.

Heat stress
According to Kasselmann (1995), the species has a maximum growth temperature (DV3) of 33-35, according to Owens and Madsen (1995), growth is retarded by 34°C. The heat stress threshold is therefore set to 38°C. It is assumed that the stress accumulates quite rapidly, and the rate is set to -0.002 (THHS). The plant is present in Mali and Niger where temperature are very high (need precise station).

Cold stress. The reported frost sensitivity of *E. crassipes* suggested that a cold stress temperature model might be appropriate. TTCS is set to 2.5 °C, this is to say that the species begins to accumulate when weekly temperatures drop below 2.5 °C, as the species is reported to suffer from the frost. A monthly average daily minimum temperature of 2.6 °C coincides with the 14th percentile, which means that on average that station would receive about one frost event per week. Since the species has been reported to remain alive at -5°C for a time but then dies, it is supposed that the cold stress accumulates moderately slowly and the rate (THCS) is set at -0.01. Cold stress appears to be the most limiting factor.

It therefore appears that records in New England in Maryland and Connecticut correspond to observations where the species is casual, and frequently introduced, as found while performing a more detailed analysis on this location (see http://nbii-nin.ciesin.columbia.edu/ipane/icat/browse.do?specieId=124). The same phenomenon is observed in Seattle in Washington State and in Moscow, where the species is recorded as casual and dying because of cold temperature during winter. Additionally, the species is recorded in botanic gardens in Amsterdam (The Netherlands), Colonia (Germany), Brno (Czech Republic) and Slovak Republic, but does not thrive there.

According to Julien (pers. comm., 2008), the species is native to Argentina. It is reported as absent from Formosa and Salta, but present in la Rioja. The CLIMEX prediction shows that the species could be present in both Formosa and Salta. According to a match climate analysis, the climate in these two cities is the same as in South Africa and the eastern coast of Australia where the species is present and invasive. There is therefore no climatic reason why the species would be absent in this area of its indigenous range. It is assumed that this is missing information from Argentina.

Comparing the distribution of the species in Spain, it appears that the species has been recorded in Yelbes (Center of Spain near Ciudad Real) and in the Laguna de Amao. It appears that Yelbes is 230 m in altitude, while Ciudad Real is at 630 m high, explaining why the CLIMEX map does not show *E. crassipes* as occurring in Ciudad Real. Additionally, Ruiz Tellez (2008a) reported that the site in Laguna de Amao (North of Spain), was protected, explaining why the CLIMEX indicates that it should not occur there due to cold stress.

Additionally to be sensitive to a cold stress, the species might be sensitive to the fact that temperatures are not high enough to allow it to photosynthesise enough to offset minimum respiration demands. The parameters are therefore set (separately from the cold stress index) to 10 for DTCS. This parameter is set upon with an accumulation rate of -0.0003 (DHCS) since the species is supposed to accumulate this stress slowly.

Growth index.
The growth indices simulate how favourable each location is for population growth, and are scaled from 0 to 100. The weekly temperature index values are integrated to give the growth index GIa, which is re-scaled from 0 to 100. The growth index for a site is set to 0 if the minimum requirement for thermal accumulation is not met.

Temperature index.
The minimum threshold for population growth, DV0, was set to 12°C, as reported by Kasselmann (1995). The minimum temperature for maximum growth rates (DV1) was set to 25°C and the upper temperature threshold for maximum growth rates (DV2) was set to 30°C, following Kasselmann (1995) observations. The maximum threshold for population growth (DV3) was set to 34°C, following the same source, and lower than the heat stress threshold.

A minimum annual heat-sum for survival was not used in this model since the plant can produce seeds and reproductive vegetative parts within 12 weeks from germination (Julien, 2008). There was nowhere within its potential range where the distribution appeared to need this requirement to constrain it.

Results

The areas estimated to be climatically suitable for *E. crassipes* under current climatic conditions are illustrated for the world (see Fig 3), and for the European and Mediterranean area (see Fig 4). The potential distribution of this species includes many countries of the Mediterranean basin: Albania, Algeria, Bosnia and Herzegovina, Croatia, France (including Corsica), Greece, Israel, Italy (including Sardinia, Sicilia), Jordan, Montenegro, Morocco, Portugal (Azores, Madeira), Slovenia, Spain (Baleares, Canarias), Turkey, Tunisia. The current distribution of *E. crassipes* is fully consistent with the projected Ecoclimatic index.
The northern boundary of the potential distribution in Europe is defined by cold stress, since this is the most limiting factor. Heat stress limits the species in Central Africa such as in Mali (Araouane), south of Algeria (Oualen Bordj), Sudan (Merowe, Dongola).

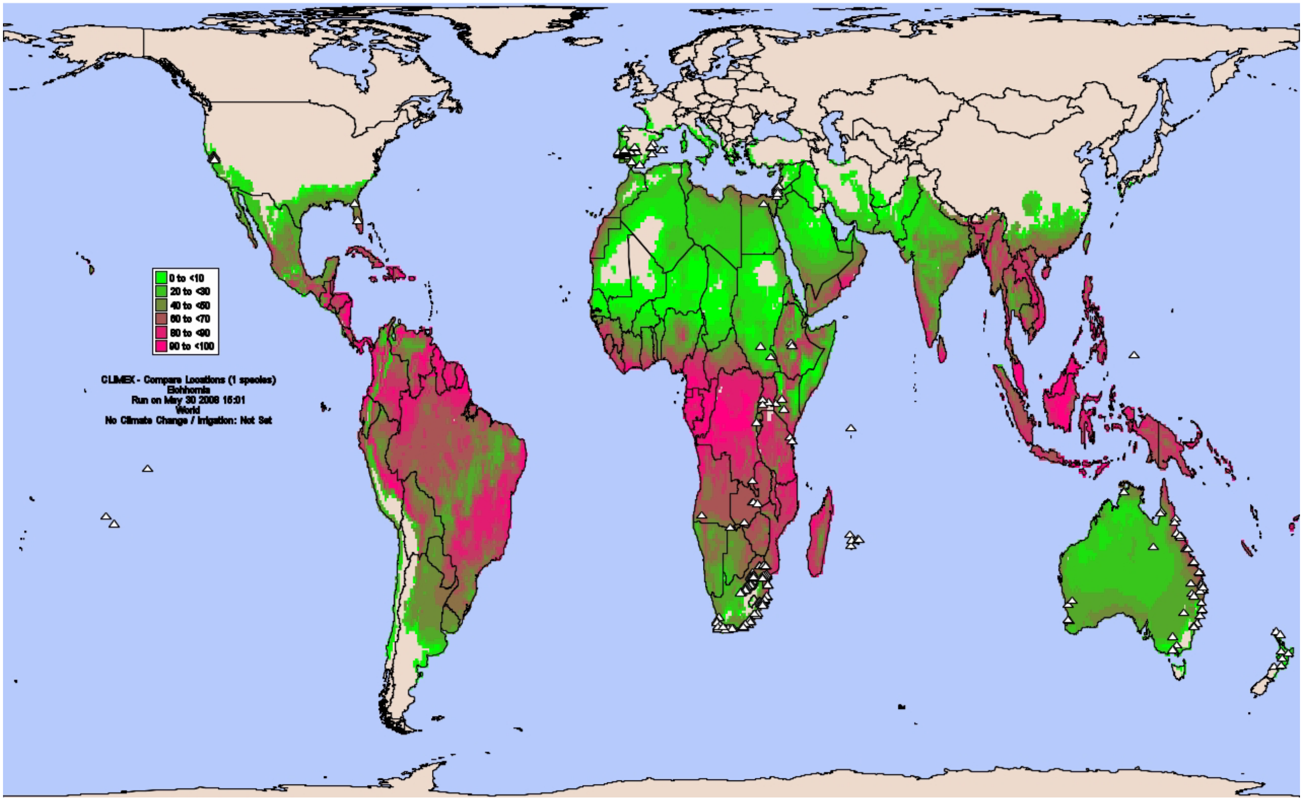


Fig 3: Potential distribution of *Eichhornia crassipes* in the world.

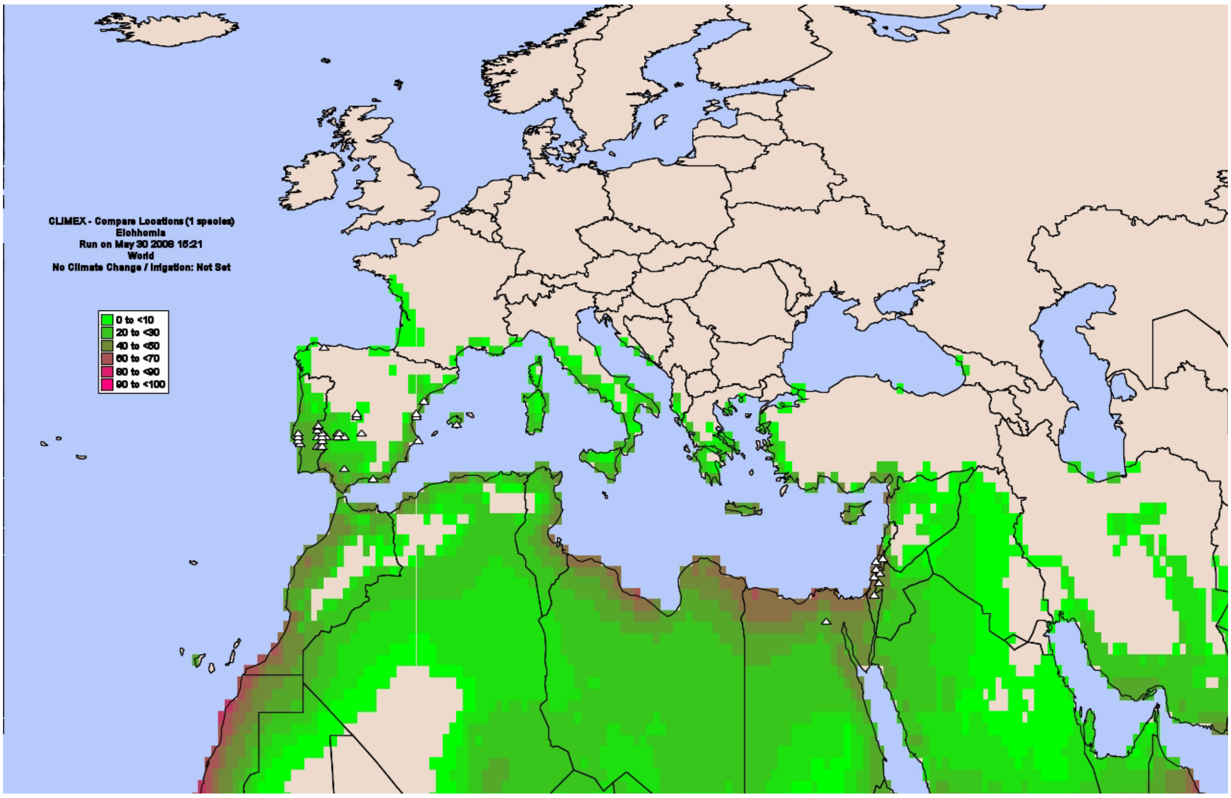


Fig 4: Potential distribution of *Eichhornia crassipes* in the EPPO region.

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